MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2022/2023

ETM4106 – OPTOELECTRONICS AND OPTICAL COMMUNICATIONS

(TE)

8 JULY 2023
9.00 a.m - 11.00 a.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 4 pages excluding the cover page with 4 Questions only.

2. Attempt **FOUR (4)** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) Briefly explain the basic elements in an optical fiber communication system. [4 marks]

(b) Write a formula for numerical aperture in terms of core refractive index, n_1 and cladding refractive index, n_2. [2 marks]

(c)(i) What are the four possible modes occur in the cylindrical optical fiber? [4 marks]

(ii) The scalar wave equation for the cylindrical homogeneous core waveguide under the weak guidance condition is given as

$$\frac{d^2\psi}{dr^2}+\frac{1}{r}\frac{d\psi}{dr}+\frac{1}{r^2}\frac{d^2\psi}{d\phi^2}+\left(n_1^2k^2-\beta^2\right)\psi=0$$

Write the range of the propagation constants of the guided modes in cylindrical optical fiber. [3 marks]

(d) An optical fiber in air has a numerical aperture of 0.4. Compare and discuss the acceptance angle for meridional rays with that for skew rays which change direction by 100° each reflection. [4 marks]

(e)(i) Write an expression for the total number of guided modes M_g supported by the graded index fiber. [3 marks]

(ii) A graded index fiber has a core with a parabolic refractive index profile which has a diameter of 50 μm. the fiber has a numerical aperture of 0.30. Estimate the total number of guided modes propagating in the fiber when it is operating at a wavelength of 1 μm. [5 marks]

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Question 2

(a)(i) What should be the core radius of a single mode optical fiber that has a core refractive index of 1.468, cladding refractive index of 1.447, and is to be used with a laser source wavelength of 1.32 μm. [4 marks]

(ii) Give your comment on the core radius of optical fiber in part (i). [2 marks]

(b) Determine the attenuation in decibels per kilometer due to the Rayleigh scattering in silica optical fiber at operating wavelength of 1310 nm. Given that silica has fictive temperature of 1400K with an isothermal compressibility of 7×10^{-11} m^2/N. The refractive index and the photoelastic coefficient for silica are 1.45 and 0.286 respectively. Boltzmann's constant is 1.38×10^{-23}J/K. [5 marks]

(c) Optical fibers suffer from radiation losses at bends or curves on their paths. Suggest two possible solutions to reduce the macrobending losses. [2 marks]

(d) Explain the following terms for dispersion in optical fiber link:

(i) Intramodal dispersion [2 marks]
(ii) Intermodal dispersion [2 marks]

(e)(i) List two examples of oxide material suitable for fiber preparation using liquid-phase techniques. [2 marks]

(ii) Describe the vapour-phase deposition techniques for silica optical fiber preparation. [4 marks]

(iii) What is the advantage of using Plasma-activated chemical vapour deposition technique? [2 marks]

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Question 3

(a)(i) The manufacturers were able to fabricate optical fibers with very low loss in the long-wavelength region. List the two low loss windows in this region. [2 marks]

(ii) Give an example of optical source which provides the electrical-optical conversion in optical fiber communication system. [2 marks]

(iii) What is the spectral band suitable for silicon photodiodes to detect the optical signal? [2 marks]

(b) Explain the following terms in laser operation:

(i) Spontaneous emission [2 marks]
(ii) Stimulated emission [2 marks]

(c)(i) Various ternary and quaternary combinations of binary compounds of semiconductor elements are suitable candidates for optical sources. Explain why the alloys GaAlAs and InGaAsP are chosen to make semiconductor light sources. [2 marks]

(ii) The excess carriers can recombine either radiatively or non-radiatively. Write the rate equation for carrier recombination in an LED. [2 marks]

(iii) A double-heterojunction InGaAsP LED emitting at a peak wavelength of 1320 nm has radiative and nonradiative recombination times of 30 ns and 100 ns, respectively. Determine the optical power generated internally to the LED when the drive current is 40 mA. [4 marks]

(d)(i) Explain the process called impact ionization in avalanche photodiode. [2 marks]

(ii) What is meant by ionization rate in semiconductor? [2 marks]

(e) A given silicon avalanche photodiode has a quantum efficiency of 60 % at a wavelength of 910 nm. Assume that 0.5 μW of optical power produces a multiplied photocurrent of 9 μA. Calculate the multiplication factor, M. [3 marks]

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Question 4

(a)(i) Write an expression of optical power budget for a digital optical communication system including the safety margin and a dispersion-equalization penalty. [4 marks]

(ii) Explain the safety margin or operating margin in optical power budget equation. [2 marks]

(b) An engineer has the following components:

(I) GaAlAs laser diode operating at 850 nm and capable of coupling 1 mW (0 dBm) into a fiber.

(II) 10 sections of cable, each of which is 500 m long with a 4 dB/km attenuation and has connectors on both ends.

(III) Connector loss of 2 dB/connector.

(IV) A p-i-n photodiode receiver.

(V) An avalanche photodiode (APD) receiver.

The engineer wishes to construct a 5 km link operating at 20 Mb/s using these components. Assume that the sensitivity of the p-i-n and APD receivers are –45 dBm and –55 dBm, respectively. Which receiver should be used if a 6 dB system operating margin is required? [3 + 3 marks]

(c)(i) What are the components of loss in a channel (channel losses) for an optical fiber communication system? [3 marks]

(ii) An optical fiber link of length 5 km comprises a fiber cable with an attenuation of 5 dB/km. The splice losses for the link are estimated at 2 dB/km and the connector losses at the source and detector are 3.0 dB and 2.5 dB respectively. Determine the total channel loss by neglecting the effects of dispersion on the link. [4 marks]

(d) The 10% to 90% rise times for possible components to be used in a direct intensity modulation (D-IM) analog optical fiber link are specified below:

Source (LED)	9 ns
Fiber cable: intermodal	9 ns/km
Intramodal	2 ns/km
Detector (APD)	3 ns

The desired link length without repeaters is 5 km and the required optical bandwidth is 6 MHz. Determine whether the above combination of components gives an adequate temporal response. [6 marks]

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